JEE Main 2020 Paper

Date of Exam: **7th January (Shift II)**
Time: **2:30 pm – 5:30 pm**
Subject: **Physics**

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1. If the weight of an object at the pole is $196\ N$, then the weight of the object at the equator is? ($g = 10\ m/s^2$; $the\ radius\ of\ earth = 6400\ \ km$)

   a. $194.32\ N$
   b. 194.66 N
   c. 195.32 N
   d. 195.66 N

   Solution: (c)
   Weight of the object at the pole, $W = mg = 196\ N$
   Mass of the object, $m = \frac{W}{g} = \frac{196}{10} = 19.6\ kg$
   Weight of object at the equator(W') = Weight at pole − Centrifugal acceleration

   $$W' = mg - m\omega^2\ R$$

   $$196 - (19.6)\left(\frac{2\pi}{24 \times 3600}\right)^2 \times 6400 \times 10^3 = 195.33\ N$$

2. In a house 15 bulbs of 45 W, 15 bulbs of 100 W, 15 bulbs of 10 W and two heaters of 1 kW each is connected to 220 V mains supply. The minimum fuse current will be

   a. 5 A
   b. 20 A
   c. 25 A
   d. 15 A

   Solution: (b)
   Total power consumption of the house(P) = Number of appliances × Power rating of each appliance

   $$P = (15 \times 45) + (15 \times 100) + (15 \times 10) + (2 \times 1000) = 4325\ W$$

   So, minimum fuse current $I = \frac{Total\ power\ consumption}{Voltage\ supply} = \frac{4325}{220} A = 19.66\ A$

3. In an adiabatic process, the volume is doubled. Find the ratio of final average relaxation time and initial relaxation time. Given $\frac{C_p}{C_v} = \gamma$

a. $\frac{1}{2}$

b. $(2)^{\frac{1+\gamma}{2}}$

c. $\left(\frac{1}{2}\right)^{\gamma}$

d. $\left(\frac{1}{2}\right)^{\frac{\gamma}{2}+1}$

Solution:(b)

Relaxation time (τ) dependence on volume and temperature can be given by $(\tau) \propto \frac{V}{\sqrt{T}}$

Also, for an adiabatic process,

$$T \propto \frac{1}{V^{\gamma-1}}$$

$$\Rightarrow \tau \propto V^{\frac{1+\gamma}{2}}$$

Thus,

$$\frac{\tau_f}{\tau_i} = \left(\frac{2V}{V}\right)^{\frac{1+\gamma}{2}}$$

$$\frac{\tau_f}{\tau_i} = (2)^{\frac{1+\gamma}{2}}$$

4. A block of mass 10 kg is suspended from a string of length 4 m. When pulled by a force F along horizontal from the midpoint. The upper half of the string makes 45^o with the vertical, value of F is

a. 100 N

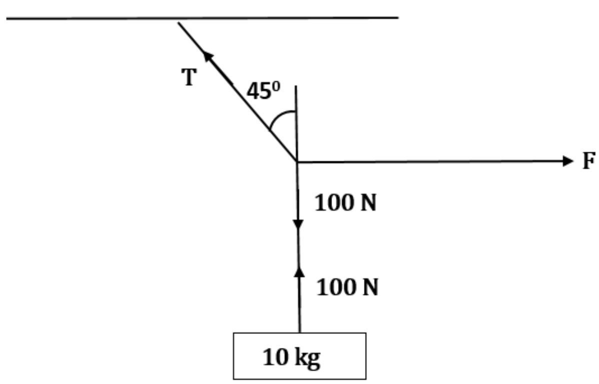
b. 90 N

c. 75 N

d. 70 N

Solution: (a)

Equating the vertical and horizontal components of the forces acting at point



$$\frac{T}{\sqrt{2}} = 100$$

$$\frac{T}{\sqrt{2}} = F$$
$$F = 100\ N$$

5. The surface mass density of a disc varies with radial distance as $\sigma = A + Br$, where A and B are positive constants. The moment of inertia of the disc about an axis passing through its centre and perpendicular to the plane is

a. $2\pi a^4 \left(\frac{A}{4} + \frac{Ba}{5}\right)$

b. $2\pi a^4 \left(\frac{4A}{4} + \frac{B}{5}\right)$

c. $\pi a^4 \left(\frac{A}{4} + \frac{Ba}{5}\right)$

d. $2\pi a^4 \left(\frac{A}{5} + \frac{Ba}{4}\right)$

Solution: (a)

$$\sigma = A + Br$$
$$\int dm = \int (A + Br) 2\pi r dr$$
$$I = \int dm\, r^2$$
$$= \int_0^a (A + Br) 2\pi r^3\, dr$$
$$= 2\pi \left(A \frac{a^4}{4} + B \frac{a^5}{5}\right)$$
$$= 2\pi a^4 \left(\frac{A}{4} + \frac{Ba}{5}\right)$$

6. Cascaded Carnot engine is an arrangement in which heat sink of one engine is source for other. If high temperature for one engine is T_1, low temperature for other engine is T_2 (Assume work done by both engines is same). Calculate lower temperature of first engine.

a. $\frac{2T_1T_2}{T_1+T_2}$

b. $\frac{T_1+T_2}{2}$

c. 0

d. $\sqrt{T_1T_2}$

Solution:
(b)
Heat input to 1^{st} engine= Q_H
Heat rejected from 1^{st} engine= Q_L
Heat rejected from 2^{nd} engine= Q_L
Work done by 1^{st} engine = Work done by 2^{nd} engine

$$Q_H - Q_L = Q_L - Q_L$$
$$2\,Q_L = Q_H + Q_L$$

$$2 = \frac{T_1}{T} + \frac{T_2}{T}$$
$$T = \frac{T_1 + T_2}{2}$$

7. Activity of a substance changes from 700 s^{-1} to 900 s^{-1} in 30 minutes. Find its half-life in minutes.

a. 66
b. 62
c. 56
d. 50

Solution:
(b)
Using the half-life equation,
$\ln \frac{A_0}{A_t} = \lambda t$
At half-life, $t = t_{\frac{1}{2}}$ and $A_t = \frac{A_0}{2}$
$\Rightarrow \ln 2 = \lambda\, t_{\frac{1}{2}}$ ------------- (1)
Also given
$\ln \frac{500}{700} = \lambda\,(30)$ ------------- (2)
Dividing the equations,
$\frac{\ln 2}{\ln\left(\frac{7}{5}\right)} = \frac{t_{\frac{1}{2}}}{30}$
$\Rightarrow t_{\frac{1}{2}} = 61.8$ minutes

8. In YDSE, separation between slits is 0.15 mm, distance between slits and screen is 1.5 m and wavelength of light is 589 nm. Then, fringe width is

a. 5.9 mm
b. 3.9 mm
c. 1.9 mm
d. 2.3 mm

Solution:
(a)
Given,
Maximum diameter of pipe = 6.4 cm
Minimum diameter of pipe = 4.8 cm

$$\beta = \lambda\frac{D}{d} = \frac{589 \times 10^{-9} \times 1.5}{0.5 \times 10^{-3}}$$
$$= 5.9\ mm$$

9. An ideal fluid is flowing in a pipe in streamline flow. Pipe has maximum and minimum diameter of 6.4 cm and 4.8 cm respectively. Find out the ratio of minimum to maximum velocity.

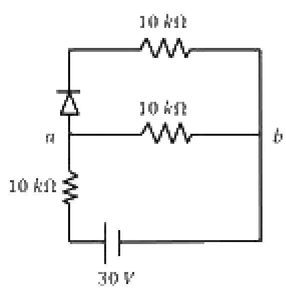
a. $\frac{81}{256}$
b. $\frac{9}{16}$
c. $\frac{3}{4}$
d. $\frac{3}{16}$

Solution:
(b)

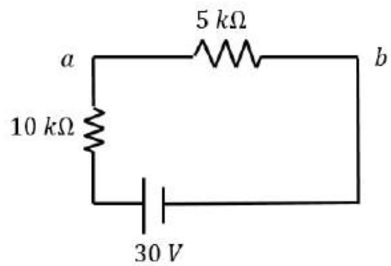
Using equation of continuity
$A_1V_1 = A_2V_2$
$$\frac{V_1}{V_2} = \frac{A_2}{A_1} = \left(\frac{4.8}{6.4}\right)^2 = \frac{9}{16}$$

10. There is an electric circuit as shown in the figure. Find potential difference between points a and b

a. 0 V
b. 15 V
c. 10 V
d. 5 V



Solution:
(c)
Diode is in forward bias, so it will behave as simple wire. So, the circuit effectively becomes



$V_{ab} = \frac{30}{5+10} \times 5 \ = \ 10\, V$

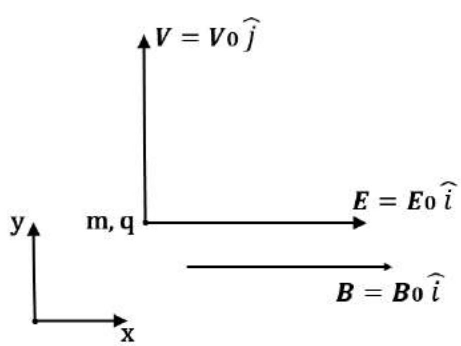
11. A particle of mass m and positive charge q is projected with a speed of V_o in y–direction in the presence of electric and magnetic field and both of them are in x–direction. Find the instant of time at which the speed of particle becomes double the initial speed.

a. $t = \frac{mV_o\sqrt{3}}{qE}$
b. $t = \frac{mV_o\sqrt{2}}{qE}$
c. $t = \frac{mV_o}{qE}$
d. $t = \frac{mV_o}{2qE}$

Solution:
(a)

As $\vec{V} = V_o\hat{j}$ (magnitude of velocity does not change in y–z plane)

$$(2V_o)^2 = V_o^2 + V_x^2$$
$$V_x = \sqrt{3}V_o$$



$$\therefore\ \sqrt{3}V_x = 0 + \frac{qE}{m}t \Rightarrow t = \frac{mv_o\sqrt{3}}{qE}$$

12. Two sources of sound moving with the same speed V and emitting frequencies of 1400 Hz are moving such that one source s_1 is moving towards the observer and s_2 is moving away from the observer. If observer hears a beat frequency of 2 Hz, then find the speed of the source (Given $V_{sound} \gg V_{source}$ and $V_{sound} = 350\ m/s$.)

a. $\frac{1}{4}$

b. 4

c. 2

d. $\frac{1}{2}$

Solution:

(a)

$$f_0\left(\frac{C}{C-V}\right)-f_0\left(\frac{C}{C+V}\right)=2$$

$$V=\frac{1}{4}\ m/s$$

13. An electron and a photon have same energy E. Find the de Broglie wavelength of electron to wavelength of photon. (Given mass of electron is m and speed of light is c)

a. $\frac{2}{C}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$

b. $\frac{1}{C}\left(\frac{E}{2m}\right)^{\frac{1}{3}}$

c. $\frac{1}{C}\left(\frac{E}{m}\right)^{\frac{1}{2}}$

d. $\frac{1}{C}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$

Solution:

(d)

λ_d for electron $=\frac{h}{\sqrt{2mE}}$

λ for photon $=\frac{hC}{E}$

Ratio $=\frac{h}{\sqrt{2mE}}\frac{E}{hC}=\frac{1}{C}\sqrt{\frac{E}{2m}}$

14. A ring is rotated about diametric axis in a uniform magnetic field perpendicular to the plane of the ring. If initially the plane of the ring is perpendicular to the magnetic field. Find the instant of time at which EMF will be maximum and minimum respectively.

a. $2.5\ sec, 5\ sec$

b. $5\ sec, 7.5\ sec$

c. $2.5\ sec, 7.5\ sec$

d. $10\ sec, 5\ sec$

Solution:

(a)

$$\omega=\frac{2\pi}{T}=\frac{\pi}{5}$$

When $\omega t=\frac{\pi}{2}$

Then φ_{flux} will be minimum

$\therefore$ e will be maximum

$t = \frac{\frac{\pi}{2}}{\frac{\pi}{5}} = 2.5\ sec$

When $\omega t = \pi$

Then φ_{flux} will be maximum

$\therefore e$ will be minimum

$t = \frac{\pi}{\frac{\pi}{5}} = 5\ sec$

15. Electric field in space is given by $\vec{E}(t) = \frac{E_0\ (\hat{\imath}+\hat{\jmath})}{\sqrt{2}} \cos(\omega t + kz)$. A positively charged particle at $(0, 0, \pi/k)$ is given velocity $v_0\hat{k}$ at $t = 0$. Direction of force acting on particle is

a. $f = 0$
b. Antiparallel to $\frac{\hat{\imath}+\hat{\jmath}}{\sqrt{2}}$
c. Parallel to $\frac{\hat{\imath}+\hat{\jmath}}{\sqrt{2}}$
d. $\hat{k}$

Solution:

(b)

Force due to electric field is in direction $-\frac{\hat{\imath}+\hat{\jmath}}{\sqrt{2}}$

Because at $t = 0, E = -\frac{(\hat{\imath}+\hat{\jmath})}{\sqrt{2}} E_0$

Force due to magnetic field is in direction $q(\vec{v} \times \vec{B})$ and $\vec{v} \parallel \hat{k}$

$\therefore$ It is parallel to $\vec{E}$

$\therefore$ Net force is antiparallel to $\frac{(\hat{\imath}+\hat{\jmath})}{\sqrt{2}}$.

16. Focal length of convex lens in air is $16\ cm$ $(\mu_{glass} = 1.5)$. Now the lens is submerged in liquid of refractive index 1.42. Find the ratio of focal length in medium to focal length in air.

a. 9
b. 17
c. 1
d. 5

Solution:

(a)

$$\frac{1}{f_a} = \left(\frac{\mu_g}{\mu_g} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{f_a}{f_m} = \frac{\left(\frac{\mu_g}{\mu_m} - 1\right)}{\left(\frac{\mu_g}{\mu_a} - 1\right)} = \frac{\left(\frac{1.50}{1.42} - 1\right)}{\left(\frac{1.50}{1} - 1\right)} = \frac{0.08}{(1.92)(0.5)}$$

$$\frac{f_m}{f_a} = \frac{(1.42)(0.5)}{0.08} = 8.875 = 9$$

17. A lift of mass 920 kg has a capacity of 10 persons. If average mass of person is 68 kg. Friction force, between lift and lift shaft is 6000 N. The minimum power of motor required to move the lift upward with constant velocity 3 m/s is $[g = 10\ m/s^2]$

a. 66000 W
b. 63248 W
c. 48000 W
d. 56320 W

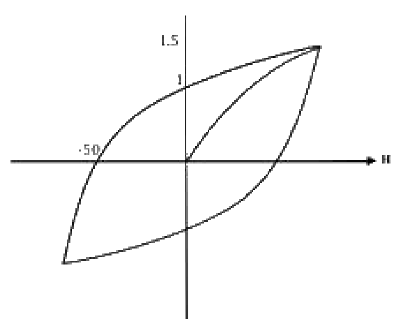
Solution:
(a)
Net force on motor will be

$$F_m = [920 + 68(10)]g + 6000$$
$$F_m = 22000\ N$$

So, required power for motor

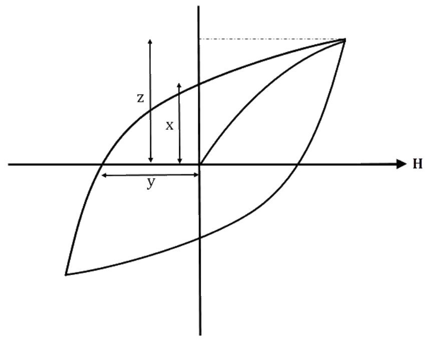
$$P_m = \overrightarrow{F_m}.\vec{v}$$
$$= 22000 \times 3$$
$$= 66000\ W$$

18. The hysteresis curve for a material is shown in the figure. Then for the material retentivity, coercivity and saturation magnetization respectively will be



a. 50 A/m, 1 T, 1.5 T
b. 1.5 T, 50 A/m, 1T
c. 1 T, 50 A/m, 1.5 T
d. 50 A/m, 1.5 T, 1 T

Solution:
(c)



x = retentivity
y = coercivity
z = saturation magnetization

19. An inductor of inductance 10 mH and a resistance of 5Ω is connected to a battery of 20 V at $t = 0$. Find the ratio of current in the circuit at $t = \infty$ to current at $t = 40\ sec$.

a. 1.06
b. 1.48
c. 1.15
d. 0.84

Solution:
(a)

$$i = i_o\left(1 - e^{\frac{-t}{L/R}}\right)$$
$$= \frac{20}{5}\left(1 - e^{\frac{-t}{0.01/5}}\right)$$
$$= 4(1 - e^{-500t})$$
$$i_\infty = 4$$
$$i_{40} = 4(1 - e^{-500\times40}) = 4\left(1 - \frac{1}{(e^2)^{10000}}\right) = 4\left(1 - \frac{1}{7.29^{10000}}\right)$$

$\frac{i_\infty}{i_{40}} \approx 1$ (Slightly greater than one)

20. Find the dimensions of $\frac{B^2}{2\mu_o}$

a. $ML^{-1}T^{-2}$
b. ML^2T^{-2}
c. $ML^{-1}T^2$
d. $ML^{-2}T^{-1}$

Solution:

(a)

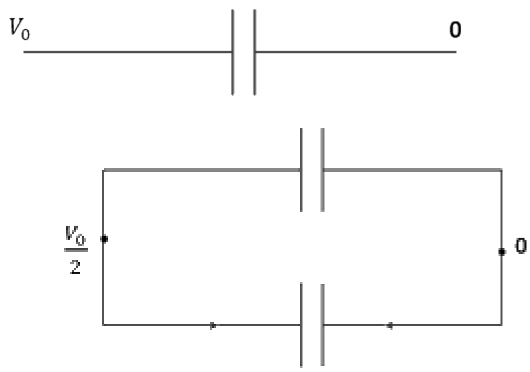
Energy density in magnetic field $= \frac{B^2}{2\mu_o}$

$$= \frac{\text{Force} \times \text{displacement}}{(\text{displacement})^{\mathbf{3}}} = \frac{MLT^{-2}.L}{(\text{L})^{\mathbf{3}}} = ML^{-1}T^{-2}$$

21. A capacitor of 60 pF charged to 20 V. Now, the battery is removed, and this capacitor is connected to another identical uncharged capacitor. Find heat loss in nJ.

Solution:

(6)



$V_0 = 20\ V$

Initial potential energy $U_i \ = \frac{1}{2}CV_0^2$

After connecting identical capacitor in parallel, voltage across each capacitor will be $\frac{V_0}{2}$. Then, final potential energy $U_f \ = 2\ [\frac{1}{2}C\left(\frac{V_0}{2}\right)^2]$

Heat loss $= \ U_i \ - \ U_f$

$$= \frac{CV_0^2}{2} - \frac{CV_0^2}{4} = \frac{CV_0^2}{4} = \frac{60\times10^{-12}\times20^2}{4} = 6\ \times 10^{-9} \ = 6\text{ nJ}$$

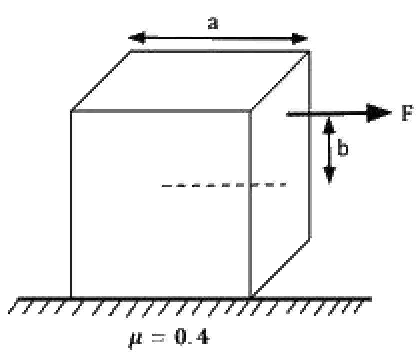
22. When m grams of steam at 100^oC is mixed with 200 grams of ice at 0^oC, it results in water at 40^oC. Find the value of m in grams

(Given, Latent heat of fusion $(L_f) = 80$ cal/g, Latent heat of vaporization $(L_v) = 540$ cal/g, specific heat of water $(C_w) = 1\ cal/g/^oC$)

Solution:

(40)
Here, heat absorbed by ice = $m_{ice}\, L_f \ + \ m_{ice}C_w(40 \ - \ 0)$
Heat released by steam = $m_{steam}\, L_v \ + \ m_{steam}C_w(100 \ - \ 40)$
Heat absorbed = heat released
$m_{ice}\, L_f \ + \ m_{ice}C_w(40 \ - \ 0) = \ m_{steam}\, L_v \ + \ m_{steam}C_w(100 \ - \ 40)$
$\Rightarrow \ 200 \times \ 80\, cal/g \ + \ 200 \ \times \ 1\, cal/g/°C \ \times \ (40 \ - \ 0)$
$= \ m \ \times \ 540\, cal/g \ + \ 540 \ \times \ 1\, cal/g/°C \ \times \ (100 \ - \ 40)$
$\Rightarrow \ 200 \ [80 \ + \ (40)1] \ = \ m[540 \ + \ (60)1]$
$m \ = \ 40\, g$

23. A solid cube of side $'a'$ is shown in the figure. Find the maximum value of c $\frac{100b}{a}$ for which the block does not topple before sliding.



Solution:
(50)
F balances kinetic friction so that the block can move
So, $F \ = \mu mg$

For no toppling, the net torque about bottom right edge should be zero

i.e $$F\left(\frac{a}{2} + \ b\right) \leq \ mg\frac{a}{2}$$

$$\mu mg\left(\frac{a}{2} + \ b\right) \leq \ mg\frac{a}{2}$$

$$F\ \mu\frac{a}{2} + \ \mu b \ \leq \frac{a}{2}$$

$$0.2a \ + \ 0.4b \ \leq \ 0.5a$$

$$0.4b \leq 0.3a$$

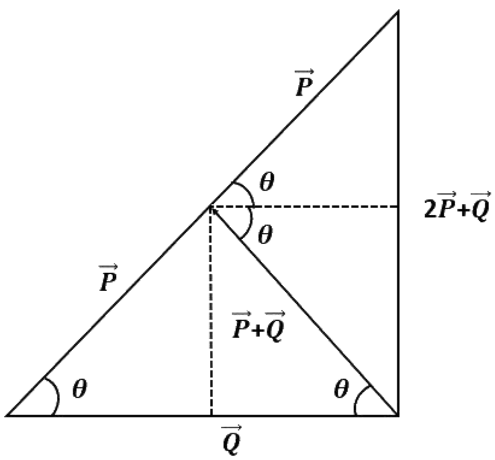
$$b \leq \frac{3}{4} a$$

But, maximum value of b can only be $0.5a$

$\therefore$ Maximum value of $100\frac{b}{a}$ is 50.

24. Magnitude of resultant of two vectors $\vec{P}$ and $\vec{Q}$ is equal to magnitude of $\vec{P}$. Find the angle between $\vec{Q}$ and resultant of $2\vec{P}$ and $\vec{Q}$.

Solution:
(90°)



25. A battery of unknown emf connected to a potentiometer has balancing length 560 cm. If a resistor of resistance 10 Ω is connected in parallel with the cell the balancing length change by 60 cm. If the internal resistance of the cell is $\frac{n}{10}$ Ω, the value of $'n'$ is

Solution:

(12)

Let the emf of cell is ε internal resistance is $'r'$ and potential gradient is x.

$$\varepsilon = 560\ x \qquad (1)$$

After connecting the resistor

$$\frac{\varepsilon \times 10}{10 + r} = 500x \qquad (2)$$

From (1) and (2)

$$\frac{560 \times 10}{10 + r} = 500\ s$$

$$56 = 540 + 5r$$

$$r = \frac{6}{5} = 1.2\ \Omega$$

n = 12